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Gill-net efficiency on fish catch based on economical and biological diversity indices

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Abstract: One of the most important methods for evaluating changes in an ecosystems is studying the biodiversity changes. This study sought to examine the changes of biodiversity in two different fishing grounds of the Persian Gulf. For this purpose, two fishing grounds were selected, Abumusa, Tonb and Siri as subarea 1, and Kish westward as subarea 2. The catching data were obtained from two fishing vessels in January 2010 and July 2011. To evaluate changes in diversity of the populations, Simpson index, economic diversity index, Shannon index and the Hill index were used. The species diversity in subarea 1 was higher than that in subarea 2. The percentage of total frequency was higher for *Tunnus tonggol* (53.34 and 37.64) and *Euthynnus affinis* (40.76 and 27.34) in both subareas. However, the economic diversification index was higher in subarea 2 and the evenness index was higher in subarea 1.

Keywords: Fish species, Diversity indices, Economic indices, Gill-net, Persian Gulf.

Introduction

The biodiversity includes composition, number, and richness of species at levels of genetic diversity within species, between species, and ecosystem level (Burely 2002). In fact, studies on the biodiversity assessments have been conducted to understand the structure and evolution of the ecosystem, preserve the genetic resources, assess and control of the environmental hazards and identify areas that are suitable for the preservation of the biological diversity (Burely 2002). Besides, the species in the environmental condition such as tropical, temperate, land or aquatic, rarely have the same abundance and frequency, and have a form that the ecosystem occupies through a dominant species (dominant species) or when the diversity is almost identical in most species, some species are less abundant or moderate (combined species and rare species); most ecosystems follow this pattern (Ghehsareh-Ardestani et al. 2010).

Persian Gulf is located in the range of 24 to 30 northern latitude and have semi-closed tropical condition (Carpenter et al. 1997) with has high species diversity (Raeisi 2012). One of the major perspectives in fisheries management is to understand the impact of changes on the biodiversity (Reid & Miller 1989). Indeed, the changes in the biodiversity affect the interaction between the species in a complex way (Kasulo & Perrings 2006) that can be useful in fisheries management.

Studies on the efficiency of gill-nets in Persian Gulf and Iranian waters is limited to some research on structure of gill-nets and data on diversity indices is scarce. Hosseini (2001) noted that the mesh size of 215 mm is the best mesh size for catching yellow-fin tuna in the surface gill-net and will be a suitable replacement for the 145 mm mesh size. Behrooz-Khoshgalb et al. (2012) reported that increasing mesh size of gill nets to 170mm for the Persian sturgeon may help achieving objectives of stock managements

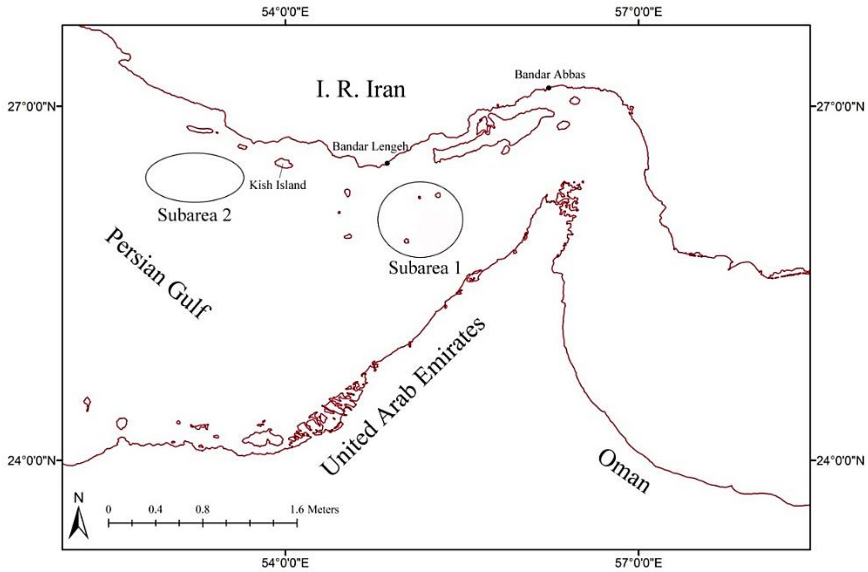

Fig.1. Map of the studied areas in the Persian Gulf.

including a decrease in catching immature fish and an increase in catching mature and larger sturgeons. Parsa et al. (2014) studied the effects of hanging ratio on the catch rate and catch per unit effort (CPUE) in gill-net. They declared that hanging ratio did not affect catch rates in gill-nets. Also, Hashemi et al. (2014) estimated the fish composition and catchability coefficient of gillnet in the Shadegan Wetland.

In this regard, gillnets are used to catch fish in column of water and it is also used as a sampling tool in some areas (Portt et al. 2006). The present study was aimed to investigate the effects of the biological diversity on the gill-nets efficiency on catching fishes in two fishing sites of the Iranian waters of the Persian Gulf to provide better economic indices for the region.

Material and method

Study area and fishing methods: The two selected fishing sites are located in Hormozgan Province waters, Persian Gulf. One region was Siri, Abumusa, Tonb (nearby Lesser and Greater Tonb waters) as the fishing ground subarea 1 and another region was Kish to west region (nearby Kish waters) as the fishing ground subarea 2 (Fig. 1). Two fishing vessels with the same gill-net type were employed for data collection. Each vessel had 10 fishing periods of 4-8 days. The same multifilament 210D15 gill-net type was used in both vessels (Net quantity: 120; Mesh size 12 cm stretch; Vessel tonnage: 45 tons). Total catch for each species and catch composition for each netting operation were recorded in winter 2010 (January) and summer 2011 (July) in order to investigate the diversity indices in different seasons. In addition, temperature was recorded by a HM Digital TDS-4TM thermometer.

Data analysis: t-test used to compare the differences between the sub regions and the two seasons, and for multiple comparison of the data, One-way ANOVA, at 95% confidence interval was employed. Simpson index is based on the number of species in the sample. The base of the measurement must be changed from number to catch rate or population biomass to use this indicator in fishing (Goda & Matsuoka 1986; Gupta 2010). Therefore, the Simpson index (biodiversity) is expressed as follows:

$$\lambda = \sum_{i=1}^{S} \left(\frac{Y_{it}}{Y_t}\right)^2$$

Y_{it} is the catch rate of the species i in time t; Y_t is the total catch in time t; S is the total species catch in time t. Gupta (2010) represents the Simpson index for the commercial species. These species are valued

Table 1. Species caught by gill net during the sampling period (January 2010 and July 2011).

Family	**Scientific name**	**Economic value by 10**
Scombridae	*Scomberomorus commerson*	10
	Euthynnus affinis	9
	Scomberomorus guttatus	8
	Tunnus tonggol	10
Synodontidae	*Saurida tumbil*	1
Carangidae	*Parastromateus niger*	8
	Carangoides chrysophry	6
	Scomberiodes commersonianus	7
Chirocentridae	*Chirocentrus dorab*	5
Lutjanidae	*Lutjanus johnii*	7
Rachycentridae	*Rachycentron canadum*	6
Haemulidae	*Pomadasys kaakan*	8
Lethrinidae	*Lethrinus crocineus*	8
Soleidae	*Brachirus orientalis*	3
Sphyraenidae	*Sphyraena jello*	4
Carcharhinidae	*Carcharhinus dussumieri*	2

according to their demand and economic value:

$$B = \sum_{i=1}^{S} \left(\frac{P_{it} Y_{it}}{TR}\right)^2$$

$TR = \Sigma P_i Y_i$

P_i is the rating of the coefficient of the species i; TR is the value of the total catch; B is the economic biodiversity index. When all fishes in catch composition have the same economic value, the diversity index is equal to the biodiversity index. If the economic species dominate in the catch composition, the economic index is higher than the biodiversity index. The same way for the Shannon index is changed as follows:

$$H' = \sum_{i=1}^{S} [(\frac{Y_{it}}{Y_t}) \text{ Ln } (\frac{Y_{it}}{Y_t})]$$

According to these two equations, the following diversity indices are available (Ludwig & Reynolds 1988):

$N_1 = e^{H'}$

Where H' is the Shannon index. $N_2 = 1/\lambda$, Where λ is the Simpson index. The evenness indices are estimated by the following equations (Pielou 1977):

$E_1 = H'/Ln(S)$

$E_2 = e^{H'} / S$

$E_3 = e^{H'} - 1 / S - 1$

Where H' is the Shannon index and S is the total catch. Hill (1973) suggests the following equation as an evenness index: $E_4 = N_2/N_1$. This ratio shows very abundant to abundant species. In fact, when the species tend to dominate both N_1 and N_2 approximates 1 (Peet 1974). Furthermore, the Hill index discusses the diversity of the population. If the diversity in a population decreases and one species tends to dominate, the value of this index approximates 1. Alatalo (1981) changed the Hill equation and represented: $E_5 = (N_2\text{-}1) / (N_1\text{-}1)$. When a species goes to dominate in the population E_5 approximates 0 and E_4 approximates 1.

Results

In total, 38571 kg, including 16 species of fishes were caught during the sampling in the two seasons by the vessels (Table 1). One-Way ANOVA showed a difference between the catch rates in the two seasons ($p<0.05$). *Tunnus tonggol*, *Euthynnus affinis* and *Scomberomorus commerson* had the highest catch rates (Tables 2 & 3).

In the both subareas the catch rates were greater in winter than summer and *Parastromateus niger*, *Chirocentrus dorab*, and *Scomberomorus guttatus* were not observed in summer at subarea 1 (Table 2), whereas, more species were missing in subarea 2 in both winter and summer (Table 3). Besides, the

Table 2. Catch rate (kg) of the species in fishing subarea 1 during the sampling period (January 2010 and July 2011).

Species	January Catch rate	July Catch rate	Total Catch	January relative frequency	July relative frequency	Total relative frequency
S. commerson	1562	3	1565	9.78	0.09	8.1
S. tumbil	40	702	742	0.25	21.06	3.8
p. niger	33	0	33	0.20	0	0.17
C. dorab	56	0	65	0.35	0	0.33
E. affinis	5437	34	5471	34.04	1.02	28.34
S. commersonianus	22	29	51	0.13	0.87	0.26
L. johnii	26	56	82	0.16	1.68	0.42
R. canadum	56	80	136	0.35	2.40	0.70
P. kaakan	186	17	203	1.16	0.51	1.05
L. crocineus	16	225	241	0.10	6.75	1.24
S. guttatus	131	0	131	0.82	0	0.67
B. orientalis	85	279	346	0.53	8.37	1.79
S. jellocuvier	36	243	279	0.22	7.29	1.44
C.dussumieri	328	1566	1849	2.05	46.99	9.58
C. chrysophrys	86	98	184	0.53	2.94	0.95
T. tonggol	7868	0	7868	49.27	0	40.76
Total	15968	3332	19300	100	100	100

Table 3. Catch rate (kg) of the species in fishing subarea 2 during the sampling period (January 2010 and July 2011).

Species	January Catch rate	July Catch rate	Total Catch	Total relative frequency	July relative frequency	Total relative frequency
S. commerson	1069	0	1069	7.93	0	5.54
S. tumbil	0	0	0	0	0	0
p. niger	6	0	6	0.04	0	0.031
C. dorab	2	0	2	0.01	0	0.010
E. affinis	4780	2472	7252	35.48	42.67	37.64
S. commersonianus	17	0	17	0.12	0	0.088
L. johnii	0	0	0	0	0	0
R. canadum	34	0	34	0.25	0	0.176
P. kaakan	0	0	0	0	0	0
L. crocineus	0	20	20	0	0.34	0.103
S. gattatus	14	0	14	0.10	0	0.072
B. orientalis	0		0	0	0	0
S. jellocuvier	21	275	296	0.15	4.74	1.53
C.dussumieri	50	190	240	0.37	3.28	1.24
C. chrysophrys	55	0	55	0.40	0	0.28
T. tonggol	7422	2835	10275	55.10	48.94	53.34
Total	13470	5792	19300	100	100	100

investigation on the frequencies showed that in both regions, *T. tonggol* and *E. affinis* had high frequency but their frequency was different in each region (Tables. 2 & 3). The frequency distribution was also more homogeneous in subarea 1. The indices differed in winter and summer in both regions as well (Table 4). In the region 1, the species diversity was much higher in winter and all the species were observed in the catch composition (Table 2). However, in region 2, this index was lower in both seasons than region 1, reflecting the lower richness of the region 2 in the catch composition. In both regions, biodiversity was higher in winter (Table 4). This difference between seasons was more evident in the region 1. The Simpson index varied from 0 to 1.

Discussion

Comparing results of catch composition of gill-net in

Table 4. Diversity indices of fish composition in two regions in Persian Gulf during the sampling period (January 2010 and July 2011).

indices	Fishing ground subarea 1		Fishing ground code subarea 2	
	January	July	January	July
Mean air temperature (ºC)	24.87±0.51	38.25±0.14	23.4±0.18	33±.70
Depth of netting (m)	40	40	36	36
λ	0.36	0.28	0.43	0.42
B	0.39	0.17	0.44	0.47
H'	1.27	1.65	0.985	0.989
N_1	3.58	5.22	2.680	2.689
N_2	2.70	3.53	2.94	2.35
E_1	0.46	0.59	0.355	0.356
E_2	0.22	0.32	0.167	0.168
E_3	0.17	0.28	0.112	0.112
E_4	0.75	0.67	0.85	0.87
E_5	0.66	0.60	0.77	0.80

Persian Gulf shows that *T. tonggol* and *E. affinis* are the most abundant species in Bushehr and Hormozgan waters (Dastbaz 2011; Parsa 2011; Moein 2013), which is coincided with our study. Parsa (2014) declared that although *S. commersonis* is one of the most valuable commercial fish species, but had a low catch rate in Bushehr waters. Study on the main fishing structure in the two regions shows that if catch composition dominated by non-target species (such as, *C. dussumieri*, *B. orientalis*, *S. tumbi*, *C. dorab*); the economic diversity index becomes less than biological diversity index which represents uneconomical condition. According to this thread, the fish biodiversity in both regions was higher in winter than summer. In addition, the economic diversity index was biased towards the species with higher economic value (Gupta 2010; Kasulo & Perrings 2006). Only in summer the economic diversity index was lower than the biodiversity index in region 1, reflecting the dominance of the species with lower economic value in the catch composition. In winter, the economic index was higher than the biodiversity index, indicating that the high economic value species were dominant in the catch composition. However, the economic diversity index might change based on the people's understanding from the economic and ecological aspects and the importance of the species on human welfare (Barbier et al. 1994). Boechlert (1996) also reported that according to the economical index, as an individual went further in the fishing process, the exploitation of higher value species shifted to exploit less valuable species. Many factors affect the aquatic biological communities such as the biological diversity and its dynamics, the ecotone, and most importantly, the distribution of the aquatic plants that contribute to the aquatic nutrition (Kolasa & Zalewsi 1995).

It is important to note that the low level of the diversity in the fishing gears might be regarded as a warning of the ecological terms, but in terms of the fishing, the ecological could be a turning point since one of the most important of the fishing discussions was the selectivity of the fishing gears on the target species; many studies have been conducted on this topic (Borgström 1989; Hamley 1975; Hosseini 2003; Santos et al. 1998; Winters & Wheeler 1990). Moreover, in an overview of all the indices, the levels of the species diversity in region 1 were higher than region 2. This was due to that region 1 was less manipulated by man than region 2 which is closer to Kish Island. In this regard, Alavian et al. (2002) declared that the wastewater pollution in coastal waters of Kish Island caused harmful effects on the abundance and distribution of the microscopic algae. They also stated that with the economical and industrial development and increasing island population, the pollution might be more than ever

before. In addition, Faezi-Razi (1997) reported the negative effects of the oil stains on both the species composition and the diversity of the rocky tidal populations in Kish Island.

In general, the diversity index was higher in winter. In fact, the only factor that affected this topic was the difference in the temperature between the two seasons. Studies on fish behavior with regard to temperature changes and its impacts on fishing showed that the temperature was a factor to change the catch rates. With respect to this, Ozbilgin & Wardle (2002) reported the temperature effect on fishing of *Melanogrammus aeglefinus*; the selectivity of the fishing gear reduced in winter and consequently, the diversity increased in the catch composition. They also stated that these changes were due to a direct effect of the temperature on the fish motion and swimming. Besides, Kitagawa et al. (2000) declared that the temperature had a great influence on the movement and the vertical distribution of *Thunnus thynnus orientalis* in the Tsushima Island. Moreover, Andrade & Garcia (1999) reported that there was not a direct relationship between the CPUE and the water temperature. However, their results not only were about the species that were distributed in the water column but also the pelagic species. They also argued that the fluctuations in the CPUE of the *T. tonggol* were in relation to the temperature fluctuations but the mechanism was unknown. To estimating the economic index, it was compared with diversity index in numerical value. Ludwig & Reynolds (1988) declared that in some cases, a given amounts of a diversity index may be obtained by different combinations of species richness and evenness. In other words, diversity indices value for a high evenness and low enriched population is the same as a low evenness and high enriched population. Thus, N and E indices were used to compare and emphasis differences between the two populations (catch composition).

The results further showed that region 1 had higher level of species diversity than region 2, but region 2 had a better condition in the economic diversity index. From an economic perspective, fishing was more economical in this region. The reviews of the seasonal temperature showed that the temperature had a significant effect on the quantity of the fish caught. The argument about the effect of season temperature on fishing process needs further studies. It can be stated that fishing in these two areas in winter was coupled with high species diversity that affected the catch rate of target species and increased by-catch.

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